A Measurement Strategy to Support Total Quality Management In a Systems Development Environment

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Abstract: This paper discusses the development and implementation of a set of measures which support a Total Quality Management (TQM) process in a Systems Development environment. This process is taking place in the background of a large Financial Institution which is seen by many as a leader in the field of Information Technology (IT). A structured quality improvement process is required in order to sustain this relative position of market leadership. In developing the strategy a brief overview of software measurement issues is presented followed by an outline of the TQM process. The Capability Maturity Model (CMM) is used in conjunction with other models to development the set of measures. Various techniques are also utilised to develop some of the measures, such as the GAPS model, used to develop a Customer Satisfaction Index. This strategy is suitable, it is argued, to a medium to large organisation with similar dynamism and complexities as the case presented. While it could be used in a small IT environment it may, however, be too elaborate for the environment.

Keywords: Software Quality Management, Software Measurement Model, Software Metrics, Total Quality Management, Software Development Quality, Systems Development Quality Assurance

Computing Review Category:

1. Introduction

Information Systems (IS) as a discipline has grown over the past 40 years by what may be described as nothing short of spectacular. With advances in technology going at a breathtaking pace, academics and IS professionals have had a non-trivial task defining the role of IT to the business. Aligning the IT strategy to the business strategy has become one of the more hotly discussed subjects lately. In fact, a close alignment of the strategies is a prerequisite for a business to reap any benefits from its IT investment [3,10]. This brings us to another contentious issue: Measurement. Can IS benefits be measured?

1.1 Software Measurement

It is a paradox that a discipline that purports to provide business with data for planning and measuring its performance cannot provide adequate data to measure itself. To quantify the benefits of a computer system is often a complex if not downright contentious issue. Business executives have become quite suspicious of any purported benefits of computer systems in the face of escalating costs [8,12]. Lincoln [8] sums it all up when he writes, "Despite the wide use of cost-benefit forecasting to justify proposed system investments, executives remain sceptical of the level of benefits actually achieved".

If the IS discipline is young the software measurement discipline is even younger. Measuring IT benefits, which is the main concern of business executives, is one thing, but measuring the software development process itself is quite another. Again academics and IS professionals have been grappling with this subject for some time now. To date there are no universally agreed measures. Each organisation follows its own methodology which is some hybrid of this or that other methodology. Project evaluation and estimation techniques sometimes consist of some antiquated and unscientific measures such as the 'man-month'. This unit of measure assumes that 'man' and 'month' are interchangeable, and confuses effort with progress [1]. The 'Function Point' measure, although much more contemporary, still requires a lot of refinement to minimise some of the subjectivity associated with the counting procedure. Meanwhile the cynicism that some business executives hold for IT and its purported benefits persists [2,8,12].

1.2 TQM in Software Development

Dr W. Edwards Deming of the United States started teaching Japanese scientists and engineers the concepts of statistical process control to improve the quality of their products as early as 1950 [7]. A few years later another American, Dr Joseph Juran, also taught the Japanese the principles of process control using statistical techniques. So, at about the same time that the IS discipline evolved did TQM also evolve - a coincidence.

The Japanese took to these statistical techniques and so internalised them that by the early 1960s they had developed them into what became known as Total Quality Control (TQC). They also showed that the principles were equally applicable to other sectors other than manufacturing. They began to apply them very successfully to the service sector. Thus a discipline that had evolved as a set of quality control techniques on the shop floor was now elevated to a management tool used by senior business executives, hence Total Quality Management (TQM).

A TQM implementation methodology embraces 8 broad principles, and these are:

1. Customer focus.
2. Management by facts.
3. Focus on processes and systems.
4. Continuous improvement.
5. Focus on root causes.
6. Empowerment of employees.
7. Assess progress against goals and adjust.
8. Training.

Therefore the second most important principle in TQM is measurement (managing by facts). While this aspect had been fairly straight forward in a manufacturing environment, it became less straight forward in a service environment, and even worse in a software development environment. As stated earlier, measuring any aspect of software is a difficult task, and adding TQM to the equation does not lessen the problem. It is almost like superimposing one immeasurable over another immeasurable and trying to measure the composite - a well-nigh impossible task. However, as it will be demonstrated in the case study below, it need not be such an insurmountable task if a structured and disciplined approach is adopted. Nonetheless, no illusions should be entertained as to the enormity of the undertaking.

1.3 Case Study

The measurement strategy described in the following sections is being applied to the Information Systems Division (ISD) of First National Bank. ISD is split into two areas, namely, Applications Development (DEV) and Operations (OPS) with more than 700 individuals between the two areas. It supports a state-of-the-art technology with more than 1200 ATMs country-wide, some 20 000 Speedpoint terminals connected to regional nodes and front-end processors, all going via a highspeed backbone X.25 network with fibre-optic technology, a wide area network linking more than 700 branches country-wide. The public SAPONET X.25 network is also used extensively.

ISD is under constant pressure to provide a better and better quality of service. Business projections show that by the turn of the century the demands on ISD will be such that unless a structured approach to provision of quality service is adopted, the whole IT infrastructure will be so inefficient that the cost of running it will become a significant cost to the whole Bank, hence the adoption of the TQM methodology.

Described in the following sections is a measurement model in line with the second TQM principle of 'Managing by Facts'.

2. A 3-D Measurement Model

2.1 Internal vs External Measures

Figure 1 below illustrates a generally accepted and proven fact that quality improvement leads to productivity improvement, which leads to a reduction in costs and to a higher customer satisfaction.

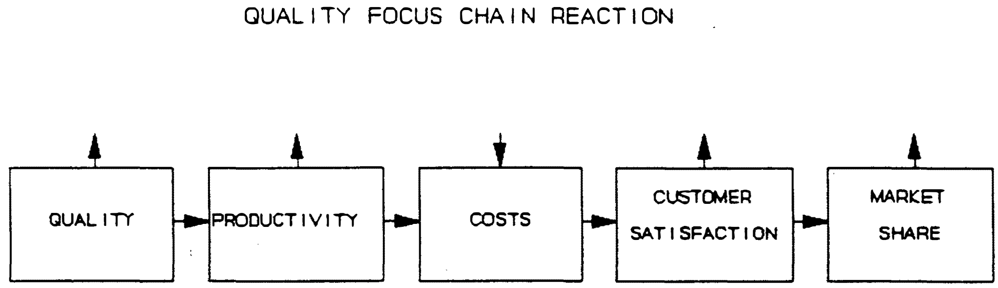

Figure 1 Quality Focus Chain Reaction

This is the basis of a set of measures used in the model. Figure 2 shows the 4 measures and how they are related to the above model.

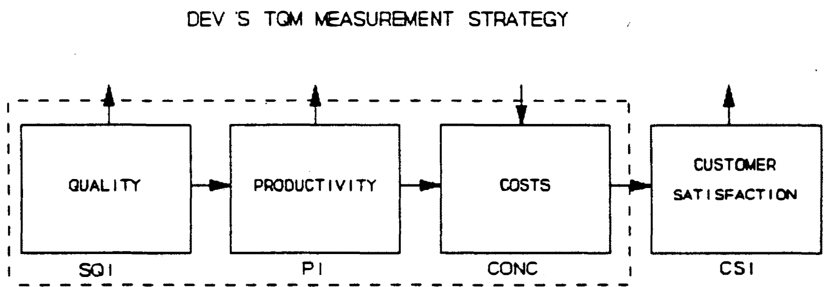

Figure 2 Internal vs External Measures

SQI	=	Service Quality Indicator
PI	=	Productivity Index
CONC	=	Cost of Non-Conformance
CSI	=	Customer Satisfaction Index

The SQI, PI and CONC are all internal or efficiency measures. They measure the 'health' of the system. The CSI is an external measure and it measures the effectiveness of the system. Efficiency measures are useful in that they are used to track the trend as other variables in the system are adjusted. Each of these measures is described in turn in the following sections. The internal and external measures comprise the two dimensions of the model. The third dimension is discussed next.

2.2 Capability Maturity Model (CMM)

The CMM describes five levels of process maturity [5]. These are illustrated in figure 3 below. This model, unlike many other organisational models, is specific to software organisations.

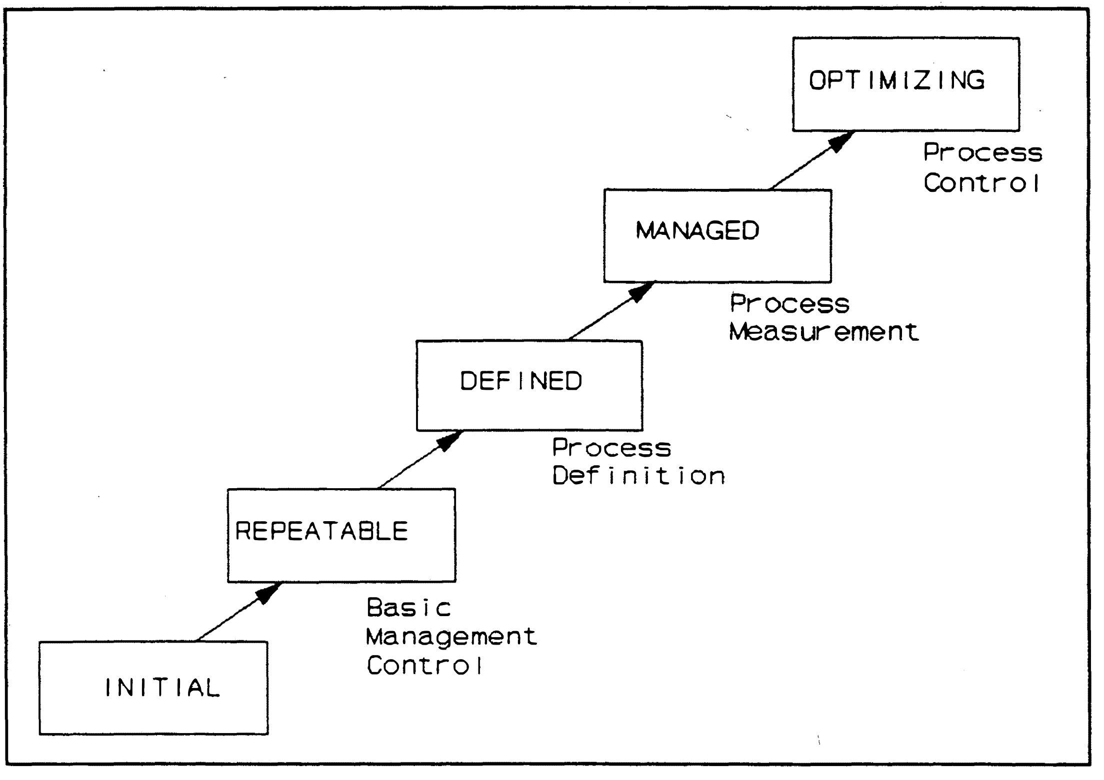

Figure 3 Process Maturity Levels

Each level in the model determines the software organisation's capability to deliver a quality software product or service. For an organisation to move up the 'ladder' certain things have to happen within the organisation. The CMM completes our 3-D model as the third dimension. A brief description of each level and what is required to move to the next level follows:

Level 1: **The Initial Process** This is the level of 'chaos' in that the organisation operates without formalised procedures, cost estimates, and project plans [11]. Tools and techniques are neither well integrated nor uniformly applied. ISD had many formal procedures in place for planning and project control. However, there was no overall mechanism to ensure their use. The introduction of a formal Project Management tool has provided the missing link. This, it would seem, is what is required to move an organisation from level one to level two.

Level 2: **The Repeatable Process** At this level the organisation has achieved some degree of statistical control through learning to make and meet its estimates and plans. This derives from experience in doing similar work. This level is risky for the organisation which feels that "it has mastered the software problem" [11]. Introducing new tools and methods often results in the whole process breaking down. Hence the need to standardize. A standard such ISO 9001 entrenches this culture and helps to move the organisation to the next level, the Defined Process. It is possible for an organisation to operate at more than one level, as in the case of ISD. However, it is also important for the organisation to understand where in the model it is operating so that it can better put its initiatives in proper perspective.

Level 3: **The Defined Process** An organisation operating at this level has achieved the foundation for a system of continuous improvement. Usually the organisation has been certified for its Quality Management System (QMS) by an auditing body, and the software teams are likely follow the process even in a crisis situation, where the process would otherwise breakdown. However, while the standard usually requires organisations to collect and use statistical data, organisations at this level have not quite internalised the use of statistical tools and techniques. The extensive use of the tools to achieve better process control moves the organisation to the next level.

Level 4: **The Managed Process** This is the level of 'Management by Facts'. All business decisions are based on data, and not on individuals' opinions. However, data collection can be quite cumbersome and disillusioning. To move to the next level the organisation has to refine the measures and automate data gathering as much as possible. At this level the data is used to modify and improve process efficiency and prevent non-conformance.

Level 5: **The Optimising Process** This process really takes place in varying degrees throughout the model. However, organisations operating at this level have guaranteed customer loyalty (as case study upon case study has shown).

In applying this model ISD's plan is to establish a correlation of the measures along the three dimensions. This will ensure that movement along one dimension can be used to predict and control movement in the other dimensions.

3. The Service Quality Indicator (SQI)

3.1 Definition of SQI

This is an adaptation of a Federal Express (US) measure which is used to identify problem areas in the system on a day to day basis. The SQI is a point system whereby a point is allocated each time a defect or nonconformity occurs in the system. It is used by individuals and teams to help track areas of concern in terms of service quality. Different types of defects are allocated different points according to some ranking agreed to by all individuals in the organisation.

Six categories of defects were identified for the SQI and these are ranked as follows:

1.	APL	3	(Application errors)
2.	OPR	3	(Operational errors)
3.	USR	1	(User-related errors)
4.	ENV	2	(Environmental errors)
5.	SSW	1	(System Software errors)
6.	REC	2	(Receipt/Output errors)

(This is a revised ranking which, together with the breakdowns in tables 1 & 2 below, are a refinement of the existing system).

The six categories are defined as follows:

APL All program code errors, program logic errors, JCL errors, online screen errors, etc.
OPR Job scheduling errors, tape errors (wrong tapes or missing tapes), batch run errors, etc.
USR Finger problems, user tables not updated, etc.
ENV Hardware problems, comms errors, damaged tapes, infra-structural problems, etc.
SSW Operating system errors, vendor-supplied software errors, etc.
REC Batch output errors such as reports, statements, letters, micro-fiche, etc. which are all 'receipts' to the customer.

3.2 Calculation of the SQI

Each time a problem is detected it is logged on a problem tracking system (Incident Reporting System). Table 1 below outlines the type of information that must be entered on the system before each incident report is closed.

Table 1 SQI Data

PBM NO.	CAT	RANK	IPCT	SIZE	SVRY	RISK	COST	URG	SQI

The various items on the SQI data record are defined in table 2 below (again, a refinement of existing system).

Table 2 Definitions of SQI Data Elements

CODE	DESCRIPTION	SCORE	DATA
IPCT	IMPACT	1	No impact to customers No impact to other systems
		3	Impact to some customers Impact to some systems
		5	Impact to many (or all) customers Impact to many (or all) systems
SVRY	SEVERITY	1	Caused no inconvenience to customers Caused no inconvenience to other systems
		3	Caused inconvenience to some customers Caused inconvenience to some systems
		5	Caused great inconvenience to some customers Caused great inconvenience to some systems Caused some inconvenience to many customers Caused some inconvenience to all systems
		10	Caused great inconvenience to all customers Caused great inconvenience to all systems
RISK	RISK	1	Exposed Bank or customers to no financial loss Exposed no system to data loss or corruption
		5	Exposed Bank or customers to financial loss Exposed some system/s to data loss or corruption
SIZE	SIZE FACTOR	$1+1/\log S$	S = Project size in function points
COST	COST FACTOR	$1+x$	x = man-hours (or a fraction thereof)

URG	URGENCY	1	No senior management involvement
		5	Divisional General Management involvement
		10	General Management involvement
		20	Managing Director's involvement

SQIs are calculated both in the systems development life cycle (SDLC) and the 'Live' environment. To calculate the SQI figure the following formulae are used:

SQI (SDLC) = ranking x impact x **size** x severity x cost
SQI (LIVE) = ranking x impact x **risk** x severity x **urgency** x cost

While the size of the change is not an issue in the 'Live' environment but Risk and Urgency (or Seriousness) of the change become very important. Hence the difference in calculation.

The IMPACT factor has to do with how many people or systems were affected by the problem, while the SEVERITY factor has to do with the extent to which people or other systems were affected. If the IMPACT is 1 then RISK, SEVERITY and URGENCY can only be 1. This means that the SQI is a bit harsher to integrated systems than to stand-alone systems.

4. The Productivity Index (PI)

This is an aggregate measure derived from CSC's Productivity Enhancement Programme (PEP) [4]. The PI is calculated by combining the two PEP measures, Function-delivery Index (FdI) and the Process-efficiency Index (PeI). The measures give an indication of the efficiency and hence productivity of the project team, using an international benchmark.

As inputs to the calculation many variables are entered such as the size of the project in function points, the number of people on the project, actual and elapsed times, technologies used such as methodologies, programming languages and 4GLs, etc. From the PEP database other factors are applied to the calculation such as language gearing and others.

Both the FdI and the PeI are expressed as a number on a scale of one to thirty. Each one point move up the scale represents a decrease in elapsed time of about 15% and a decrease in effort of about 20%. This is true of both measures. However, the average FdI is about 11 with a standard deviation of 3, and the average PeI is about 15 with a standard deviation of 3. Again, these averages come from the international PEP database with data obtained from a number of countries [4].

Thus, PI = (FdI + PeI)/2.

It must be emphasized that the PI, as with all the other measures, is merely an indication of a trend. It is not the absolute value that is important but the historical trend. The measure should be able to show an improvement or a decline. The accuracy of the measure will perhaps help detect the slightest movements, but this is not the goal.

Based on the average values for FdI and PeI, the benchmark for PI is 13 with a standard deviation of 3.

5. Cost of Non-Conformance (CONC)

There are two broad categories of costs related to quality. These are: Cost of conformance (or cost of quality), and cost of non-conformance (or failure costs). Cost of conformance includes those costs that must be incurred in order to ensure quality, while cost of non-conformance includes all costs incurred as a result of poor quality. The two categories are further broken down as follows:

Cost of Quality (COQ):	-	Prevention costs
	-	Appraisal costs
Cost of Non-Conformance (CONC):	-	Internal failure costs
	-	External failure costs

A quality management system that focuses more on the cost of non-conformance and ignores prevention and appraisal is called a detection system. In this situation CONC is very high, while a prevention system puts more emphasis on prevention and drastically reduces its CONC.

There are indirect costs of non-conformance which are usually quite difficult to measure. These are:

1. Lost opportunity costs.
2. Loss of customer goodwill.
3. Erosion of market share.
4. Liabilities.
5. Penalties.
6. Loss of reputation.

Although some of these costs may be fairly easy to measure, such as penalties, in some cases it might be difficult to attribute them to one specific error. However, where this is possible they are included in the CONC calculation. Data for calculating CONC is captured via the incident report in the following format:

Table 3 CONC Data Record

PROBLEM NO. XXXXXXXXXXXX	NO	RATE	TOTAL
MAN-HOURS			
STAFF OVERTIME			
STAFF TRAVEL			
OPPORTUNITY COSTS			
LIABILITY CLAIMS			
PENALTIES			
LOST BUSINESS			
REPLACEMENT COSTS			
OTHER COSTS			
TOTAL COSTS			
QUALITATIVE COSTS			

Empirical research conducted in the US has revealed that companies that are on a detection system spend 25% to 40% of their sales figure on quality-related errors, and 75% of that is CONC. Companies that are on a prevention system spend only about 5% of their sales figure on quality-related errors, and only 30% of that is CONC [13].

6. Customer Satisfaction Index (CSI)

Quality is a customer determination, not an engineer's determination, not a marketing determination or a general management determination. It is based upon the customer's actual experience with the product or service, measured against his or her requirements - stated or unstated, conscious or merely sensed, technically operational or entirely subjective - and always representing a moving target in a competitive market [5].

6.1 Outline of the GAPS Model

The GAPS Model defines what are known as ten dimensions of service quality [14]. These dimensions or categories are the means by which a customer evaluates the quality of a product or service, consciously or subconsciously. The model also defines an 'Expected Service' and a 'Perceived Service' which constitutes a 'gap' in the customer's eyes. Figure 4 below illustrates the model.

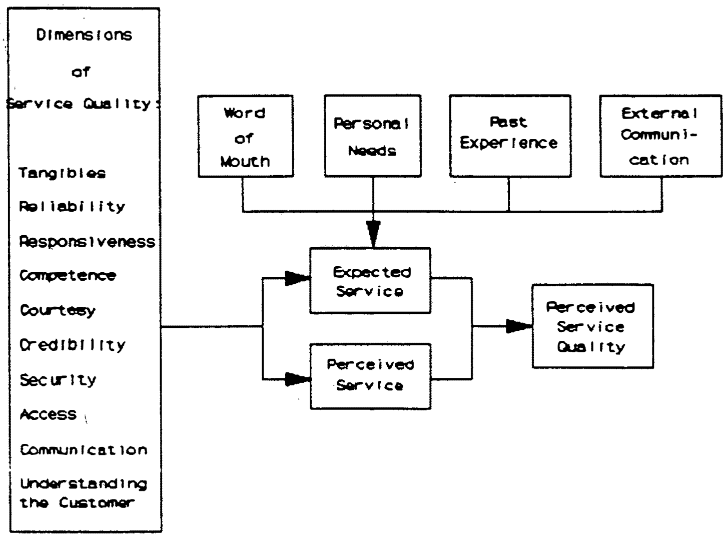

Figure 4 Customer Assessment of Service Quality

Parasuraman et al, developed a tool for measuring the service quality gap which they called SERVQUAL. Their extensive research further revealed strong correlations among some of the dimensions which resulted in the consolidation of the last seven dimensions into two broad dimensions labelled "Assurance" and "Empathy". Figure 5 below illustrates the correspondence between the original ten dimensions and SERVQUAL's five dimensions.

Central to the customer service drive was the question of who is ISD's customer. This is important because SERVQUAL is a generic instrument which must be tailored for the organisation. Figure 6 defines ISD's customer service value chain, with a Division known as systems and support which plays the business analysis function. This is to ensure that systems are developed according to business needs. The survey was only directed to internal customers only, that is, Banking Divisions and Systems and Support as well as a few branches. The results of the Gaps internal survey were used to derive the CSI.

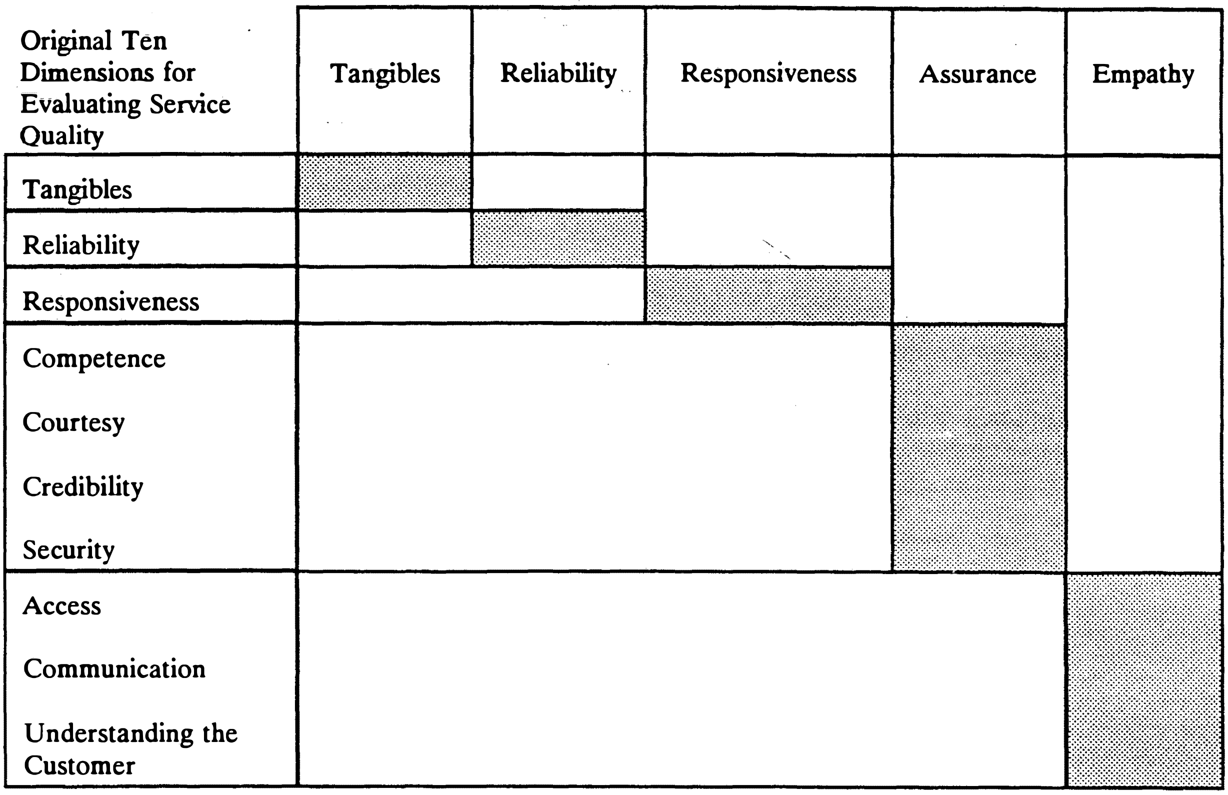

Figure 5 Correspondence Between SERVQUAL Dimensions and Original Ten Dimensions

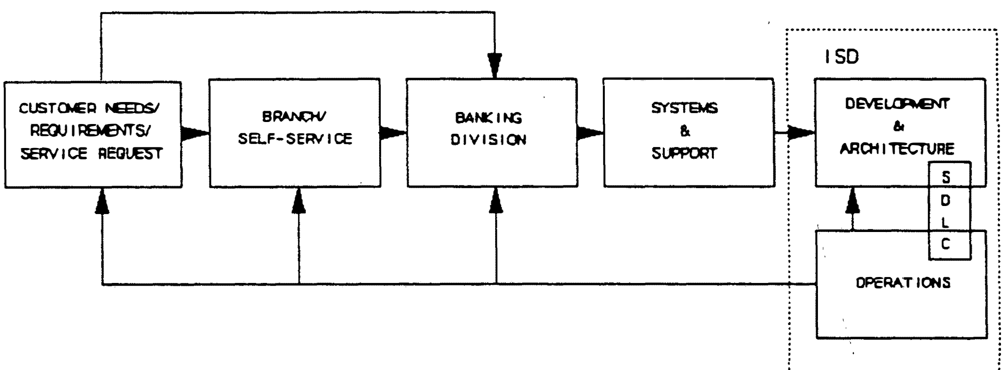

Figure 6 ISD's Customer Service Value Chain

6.2 Results of Internal Survey

Table 4 below illustrates the result from the internal survey. The important columns are the weighted gap column and the %RESP column. The perception column is used to derive the CSI.

%RESP means the percentage of respondents who believe that this dimension is the most important. The results confirmed empirical theory that RELIABILITY is weighted the highest by customers and organisations often do the worst in that category, usually focusing on TANGIBLES!

Table 4 ISD's Customer Service Gap

DIMENSION	PERCEP.	EXPECT.	GAP	WEIGHT	WTD GAP	% RESP
TANGIBLES	4,77	4,99	-0,22	0,07	-0,24	0,0
RELIABILITY	3,70	6,62	-2,92	0,44	-4,21	76,9
RESPONSIVENESS	4,20	6,36	-2,16	0,19	-2,56	3,8
ASSURANCE	4,43	6,36	-1,93	0,19	-2,29	5,8
EMPATHY	4,37	6,33	-1,96	0,11	-2,17	0,0

By converting the PERCEPTION column into a 100-point scale a CSI is obtained. The CSI is calculated once every 6 months for the whole Division and then at every post implementation review (PIR), a project by project CSI is taken. This enables teams to aim to beat the Divisional CSI thus focusing on satisfying their customers. The project CSIs are then rolled up to the Divisional level.

7. Summary and Conclusion

The essence of measuring the software development process initially is to lay the foundation for improvement. However, care has to be taken to ensure simplicity of the measures. Accuracy is not a critical issue initially as the emphasis is more on revealing trends in the process. However, consistency is more important to ensure that the process is understood across the board. Once the measures are entrenched emphasis should then shift to the CMM. This is now to drive the organisation up the process maturity ladder. The measures will highlight what is happening to the system, but the breakthroughs will be achieved by focusing on climbing the process maturity ladder.

Smaller IT organisations may find this model a bit too elaborate. However, a better control for the process might be achieved a lot more easily in such an organisation that only one or two measures might be used.

The implementation process at ISD is not complete. But the next twelve months should prove quite informative.

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